



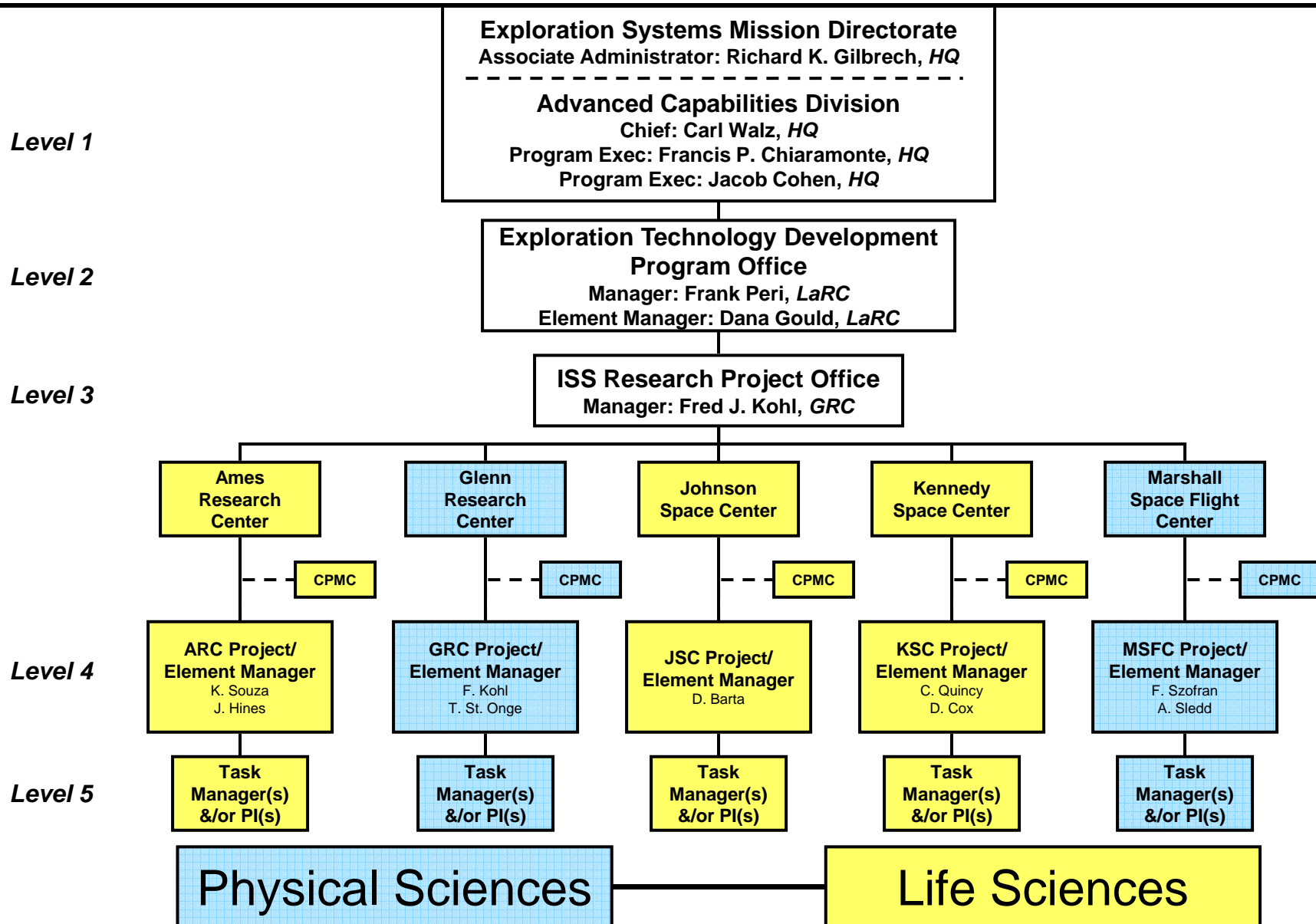
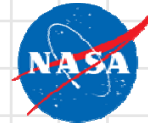
# **NASA's Plans for Materials Science on ISS:**

## **Cooperative Utilization of the MSRR-MSL**

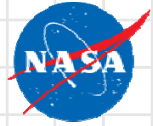
Francis Chiaramonte  
Program Executive  
Headquarters

Frank Szofran  
Project Manager  
Marshall Space Flight Center

# ISS Research Project Organization



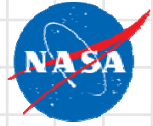
# ISS Research Project



- The ISS Research Project draws Life (non-human) and Physical Sciences investigations on the ISS, free flyer and ground-based into one coordinated project. The project has two categories:
  - **Exploration Research Program** –
    - Utilizes the ISS as a low Technology Readiness Level (TRL) test bed for technology development, demonstration and problem resolution in the areas of life support, fire safety, power, propulsion, thermal management, materials technology, habitat design, etc.
    - Will include endorsement letters from other ETDP projects to show relevancy.
  - **Non-Exploration Research Program** –
    - Not directly related to supporting the human exploration program. Research conducted in the life (non-human) and physical sciences.
    - The program will sustain, to the maximum extent practicable, the United States scientific expertise and research capability in fundamental microgravity research.
- Physical Sciences has about 44 grants, and Life Sciences has approximately 32 grants, mostly with universities, to conduct low TRL research; this includes grants to be awarded from the 2008 Fluid Physics and Life Science NRA's.

# ISS Exploration and Non-Exploration Research Project

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## Focus: Research on Gravity-Dependent Phenomena

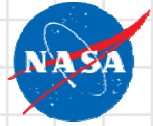
### Physical Sciences

Combustion Science  
Fluid Physics  
Fundamental Physics  
Materials Science  
  
Acceleration Environment  
Characterization

### Life Sciences

Animals  
Plants  
Microbiology  
Cell and Molecular  
Biology  
Immunology  
Physiology  
Genetics

# Combustion Science – Exploration



## **Description:**

Combustion experiments on the ISS will investigate smoke detection, fire suppression and material flammability in space craft conditions. These studies will investigate the fundamental underpinning phenomena that control combustion in reduced gravity and address specific spacecraft fire protection technology issues.

## **Applications:**

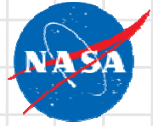
The SAME experiment studied smoke from 5 different materials that are representative of materials found in the pressurized volume of a spacecraft, making measurements to determine the particle size distribution. These results indicate that some materials (Teflon and Kapton) produce smoke particles that are beneath the size threshold for light scattering detectors such as are used on the ISS. Rejection of false alarms may be achievable by detecting at the sub-micron level and using size selective smoke detection. These results are being communicated to the Constellation Environmental Control and Life Support System (ECLSS)/Thermal System Integration Group (SIG).

## **Experiments:**

- Dust and Aerosol measurement Feasibility Test (DAFT) – 2006, MSG
- Smoke Aerosol Measurement Experiment (SAME) – 2007, MSG
- Multi-User Droplet Combustion Apparatus (MDCA)/FLame Extinguishment eXperiment (FLEX) – 2009, CIR
- Flammability Assessment of Materials for Exploration (FLAME) – 2013, CIR

# Fluid Physics – Exploration

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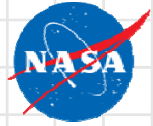
## **Description:**

Fluid experiments will investigate multiphase flow, phase change and heat transfer phenomena that provide the underpinning for propellant storage, energy transport, thermal management, power generation and life support systems. Areas of investigation include fluid mixing, phase separation and capillary driven shapes and flows. The low gravity data will be used as a benchmark for validating numerical and analytical models.

## **Applications:**

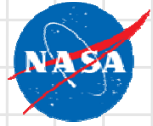
CFE - PI Prof. Mark Weislogel is working with the Life Support and Habitability Systems Branch at JSC (E. Thomas and J. Graf) to incorporate CFE (ICF-1 and -2) geometries into design of a CEV urine collection device utilizing passive phase separation, that has a potential 20% mass savings over the baseline. Initial tests of prototype design on C-9 low gravity aircraft are promising and an invention disclosure has been submitted.

# Fluid Physics – Exploration



## Experiments :

- Capillary Flow Experiment, (CFE and CFE-2) – 2007, MWA
- Capillary Flow Experiment -2, (CFE-2) –2010, MWA
- Constrained Vapor Bubble, (CVB) – 2010, LMM/FIR
- Microheater Array Boiling Experiment, (BXF/MABE) – 2010, MSG, with ESA
- Nucleate Pool Boiling eXperiment, (BXF/NPBX) -2010, MSG
- Capillary Channel Flow (CCF) – 2010, MSG, with DLR
- Zero Boil-Off Tank Experiment, (ZBOT) – 2012 in MSG,
- Zero Boil-Off Tank Experiment-2, (ZBOT - 2) – 2013, MSG or FIR
- Two-Phase Flow Separator – 2013, MSG or FIR
- Flow Boiling - 2015, FIR
- Zero Boil-Off Tank Experiment -3, (ZBOT- 3) – 2015, MSG or FIR



# Combustion Science – Non-Exploration

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## **Description:**

The combustion experiments on the ISS are focused on study of the fundamental processes in combustion that are affected by buoyant flow. The low-gravity conditions on the ISS enable establishment of simplified 1-dimensional systems that can be rigorously modeled and allow visibility into weaker effects that are masked by buoyancy. The low gravity results will be used to benchmark numerical simulations and to investigate parameters spaces that are inaccessible on earth.

## **Applications:**

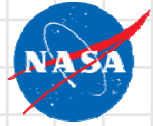
These experiments will improve our understanding of soot emission, soot formation, soot production, flame structure and flame stability. These investigations support improved fuel efficiency and pollutant reduction in practical combustion systems (jet engines, cars, power generation, heaters, etc.) by pursuing enhanced combustion through targeted flame design.

## **Experiments:**

- Smoke Point in Coflow Experiment (SPICE) – 2010, MSG
- FLame Extinguishment eXperiment-2 (FLEX-2) – 2011, CIR
- Advanced Combustion via Microgravity Experiments (ACME) – 2013, CIR



# Fluid Physics – Non-Exploration



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## Description:

The current generation of fluid experiments focus on colloidal and liquid crystal systems. The Light Microscopy Module will be used for some of these experiments. Colloidal investigations will study small colloidal particles used to model atomic systems and engineer new systems without sedimentation and particle jamming. Liquid crystal investigations will exploit the unique characteristics of freely suspended liquid crystal films. Gravity driven sedimentation produces inhomogeneities in film thickness, precluding the formation of large, homogeneous, boundary-free films in Earth's gravity.

## Applications:

BCAT-5 Experiment – Samples 1 to 5 to be conducted by Proctor and Gamble to address Phase Separation:

- “Fabric enhancers are composed of mixtures of vesicle and polymers which, in some cases, form weak particle gels. These gels often coarsen exhibiting sintering, cracking or collapse, which significantly reduce the product shelf life. The factors that contribute to coarsening are enigmatic, as the processes are often concealed by the gravitational compression of the gel. Microgravity experiments offer a unique opportunity to elucidate coarsening mechanisms in these weak gel systems.” P&G, Dr. Matthew Lynch
- Liquid crystal investigations will provide clues to improve the contrast, resolution, and faster response of the liquid crystal based on the very high-definition display devices that are currently used on the helmet-mounted and heads-up display systems.

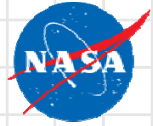
# Fluid Physics – Non-Exploration



## Experiments :

- Physics of Colloids Spheres (PCS) – 2001, EXPRESS
- Gradient Driven FLuctuations Experiment (GRADFLEX) – 2007 (Free Flyer payload) ESA-led experiment
- Investigating the Structures of Paramagnetic Aggregates from Colloidal Emulsions, (InSPACE-1,-2,-3) – 2007, 2008, 2010, MSG
- Shear History Extensional Rheology Experiment, (SHERE) – 2009, MSG
- Binary Colloidal Alloy Test (BCAT-3,-4,-5) – 2007, 2009, 2010, MWA, with CSA and Proctor and Gamble
- Self-Structuring in Dusty Plasmas 3 and 4 (DustyP-3 and -4) – 2011, 2012 ESA and Russia-led experiments
- LMM/Observation and Analysis of Smectic Islands in Space (OASIS) – 2011, LMM/FIR
- Foam Optics And Mechanics (FOAM) – 2011, ESA-led experiment
- LMM/Advanced Colloids – 2013, LMM/FIR, with ESA and CSA

# Materials Science



## Description:

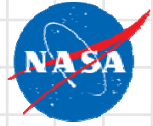
Materials Science investigations will allow for increased understanding of processes which can be used to improve yield or properties of technologically important materials for earth applications. These experiments will aim to **improve the understanding of impurity/dopant incorporation and defect formation in semiconductors, microstructure formation in metals and alloys**, and measurement of thermophysical properties.

## Applications:

Applications include **improved semiconductor sensors for astronomical observation, security, and defense, e.g. providing lower defect-density substrates for infrared sensors**. Quasicrystal structures have industrial potential for hydrogen storage, infrared detectors, battery components, and high temperature corrosion resistant coatings. **Improved processing parameters also have the potential to yield materials such as stainless steel and aluminum alloys with better properties at reduced cost.**

# Materials Science – ISS, Completed

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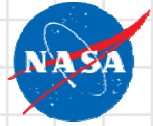


## **Non-Exploration Experiments:**

- Coarsening in Solid Liquid Mixtures-2 (CSLM-2) – 2003, 2008 MSG
- Fluid Merging Viscosity Measurement (FMVM) – 2004-2005 MSG
- Viscous Liquid Foam – Bulk Metallic Glass (FOAM) – 2004 MSG
- Miscible Fluids in Microgravity (MFMG) – 2003-2005 MSG
- Toward Understanding Pore Formation and Mobility During Controlled Directional Solidification in a Microgravity Environment (PFMI) – 2003, 2006 MSG
- Solidification Using a Baffle in Sealed Ampoules (SUBSA) – 2002 MSG
- Zeolite Crystal Growth (ZCG) – 2001-2003 MSG

## **Exploration Experiment:**

- In Space Soldering Experiment (ISSI) – 2003-2005 MSG

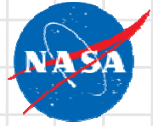


## Non-Exploration Experiments:

- Dynamic Selection of Three-Dimensional Interface Patterns in Directional Solidification (DSIP) – DECLIC, CNES-led experiment.
- Comparison of Structure and Segregation in Alloys Directionally Solidified in Terrestrial and Microgravity Environments (MICAST/CSS) – MSRR, ESA-led experiment.
- Crystal Growth of Ternary Compound Semiconductors (GTS) – MSRR, ESA-led experiment
- Reduction of Defects in Germanium Silicon (RDGS) – MSRR, ESA-led experiment
- Space Investigation of Nucleation in Undercooled Liquids (SINUL) (formerly QUASI) – EML, DLR-led experiment
- The Role of Convection and Growth Competition in Phase Selection in Microgravity (LODESTARS) – EML, DLR-led experiment

# MSRR-MSL U.S. Team Members/Objectives

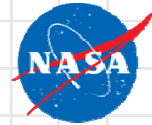
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- Prof. David Poirier, University of Arizona (MICAST/CSS)
  - Examine the effects of changing solidification rate on the dendritic microstructure in directionally solidified metallic samples
  - Examine the effects of cross-sectional changes during directional solidification on the distribution of primary dendrite arm spacings and their crystallographic orientation and on the micro- and macro-segregation.
- Dr. Martin Volz , NASA Marshall Space Flight Center (RDGS)
  - Determine the improvements attainable in defect and impurity incorporation in Ge-Si alloys by detached as opposed to normal Bridgman growth.
  - Improve understanding of parameters related to detachment during Bridgman growth.
- Dr. Ching-Hua Su, NASA Marshall Space Flight Center (GTS)
  - Establish contributions of gravity-driven flows to incorporation of defects and impurities, and deviation from stoichiometry in II-VI ternary compounds.



# Materials Science Research Rack (MSRR)



Marshall Space Flight Center

PM: Jimmie Johnson, 256.544.0852

Engineering Teams: SDOS, Jacobs, HEI

## Objective:

- To provide a facility onboard the ISS to conduct materials science research/technology experiments by:
  - Providing a modular facility to accommodate up to two Experiment Modules (EM)
  - Providing for the facility integration of the ESA MSL EM
  - Successfully supporting the planned investigations through the mission
  - Providing resources for experiment modules: power, data, vacuum (resource and exhaust), cooling, microgravity isolation, video.

## Relevance/Impact:

- The MSRR can be utilized for multi-Program tasks
- The MSRR will accommodate the operation of the European Space Agency Materials Science Laboratory (MSL)**

## Development Approach:

- The MSRR Experiment Carrier (EC) consists of the Rack Support Subsystems (RSS), an Active Rack Isolation System (ARIS) and the International Standard Payload Rack (ISPR) with its Standard Payload Outfitting Equipment (SPOE).
- The MSRR is a multi-purpose International Space Station (ISS) facility capable of accommodating a wide variety of research experiments to conduct material science and technology investigations in micro-gravity
- The MSRR Facility is being designed and developed by the Marshall Space Flight Center, this effort is managed out of the Science and Mission Systems Office (VP)



## Experiment Accommodations

<b>Experiment Volume (Alpha side) (7.3 ft<sup>3</sup>)</b>	31.75" length x 15.7" depth x 25.37" width
<b>Launch Mass Available (Alpha side)</b>	Max – 107 kg (cg constraints must be analyzed)
<b>Power Available To Experiments (1000 watts total)</b>	5 kW maximum based on two payload operations 2 - 10 amp @ 120 Vdc 8 – 10 amp @ 28 Vdc
<b>Cooling Available</b>	MTL Coolant available Maximum pressure drop = 5.5 psi
<b>Video</b>	NTSC signal per EIA/TIA RS-250-C
<b>Vacuum</b>	VES and VRS access
<b>Data Handling</b>	MRDL Ethernet link to LAN-2 MIL-STD-1553B Remote Terminal interface to Master Controller (Bus Controller)

Revision Date: 05/06/08

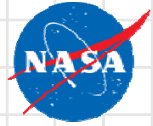
## Project Life Cycle Schedule

Milestones	LOA	IPL PDR	IPL CDR	JIP	Eng Unit Del	MSFC CoFR	Flight Unit Del	Launch	Transfer of Ownership	Ops	Return
<b>Actual Dates</b>	09/1999	02/2000	04/2002	07/2003	04/2006	TBD	01/20/08	17A, STS-128 07/2009 w/LGF	N/A	TBD	TBD

Coordination Meeting 23-25 JUNE 2008

# Operational Plans for the MSRR

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- The MSSR is scheduled for launch on 17A in July 2009.
- Current agreement between ESA and NASA for the operation of the MSRR on the ISS is that NASA will operate the MSRR and process samples for the first two years aboard the ISS.
- Downmass capability after cessation of Shuttle operations will present a challenge to returning sample cartridges.
- Continued operation of the MSRR after two years is being discussed at the Program level, specifically, Rod Jones (NASA) and Martin Zell (ESA).